

Dynamic Voltage Restorer for Compensation of Voltage Sag: An Overview

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Abstract— Power quality is the major concern in today electrical power system. One of the major issues in improving power quality in distribution network. In distribution system voltage sag, voltage swell, harmonic interruption etc. are the main power quality problem. Among out of these, the voltage sag are most severe disturbances. To solve this problem, custom power devices are used. The DVR is a powerful device or a controller that is commonly used for voltage sags mitigation at the point of connection. DVR is fast, flexible and efficient solution to voltage sag problem. The DVR is a custom power device (CPD) which is connected in series with the network to maintain precise voltage in electrical distribution system. A DVR inject a voltage in series with the system voltage. This paper describes the principle of DVR operation, basic component, DVRs topologies system in distribution system, modeling and analysis of DVR. Fault are applied for DVR in distribution system and response of the system for this disturbances are observed. The result are achieved by using MATLAB.

Key words: Dynamic Voltage Restorer (DVR), Voltage Sag

I. INTRODUCTION

Power quality is the major concern in the present era [3]. Power quality can be defined as having a bus voltage that closely resembles a sinusoidal waveform of required magnitude. Increasing number of sensitive devices to variations, the requirement for reducing losses and the behaviors of interconnected networks are some reasons which increases the importance of power quality concept. Fault at either the transmission or distribution level may cause voltage sag or swell or interruption etc.in the entire system. Voltage sag can occur at any instant of time, with amplitudes ranging from 10-90% and a duration for half a cycle to one minute [1]. Voltage swells are not as important as voltage sag because they are less common in distribution system. Voltage sag or swells can cause sensitive equipment to fail, or shutdown.

There are many different methods to mitigate voltage sag and swells, but the use of a custom power devices is considered to be the best method. The concept of custom power was introduced by N.G. Hingorani in 1995 [1]. Like flexible AC Transmission System (FACTS) for transmission system, the term custom power pertains to the use of power electronics controllers in a distribution system, especially, to deals with various power quality problems.

In order to mitigate the voltage disturbance custom power devices such as dynamic uninterruptible power supply, dynamic voltage restorer, DSTATCOM have been proposed [2].

In this paper we are discussing only DVR

A. Configuration of DVR

Fig.1 show the basic configuration of DVR

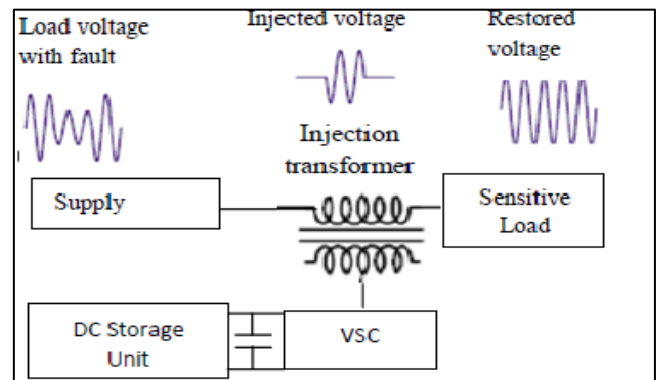


Fig. 1: Dynamic voltage restorer (DVR)

DVR is a solid state power electronics switching devices having following components [6]:

B. Storage Unit

The function of storage unit is to supply the necessary energy to the VSC for converting DC to AC signal. Batteries, ultracapacitors, SMPS etc. are the most common types of energy storage devices [5]. We can give the energy to the VSC from the supply mains through a rectifier. This type configuration is known as without storage configuration.

C. Voltage Source Converter (VSC)

In this we use the voltage source inverter (VSI). It is a power electronics device consisting of switching device and a storage device [1] [3].

The function of an inverter system in DVR is used to convert the DC voltage supplied by the energy storage device into an AC voltage at any required magnitude, phase and frequency to compensate the load voltage at the required voltage.

1) Switching Devices

Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off Thyristor (GTO), Insulated Gate Bipolar Transistor (IGBT) are main types of the switching devices. Insulated Gate Bipolar Transistor (IGBT) is considered to be a newer device compared to MOSFET and GTO, first introduced in the early 1980s and has become a popular device because of its superior characteristics [1].

D. Injection Transformer

Injection Transformer couple the VSC to the distribution line. Injection Transformer limits coupling of noise and transient energy from primary to secondary side. HV side of the injection transformer is connected in series to the distribution line and the power circuit of the DVR can be connected at the LV side. In case of DVR the injection transformer in series. When the voltage level is decreased in the transmission line then the transformer inject the voltage with required magnitude and frequency. Transformer also isolate the line from the VSC [5] [1].

E. Control Unit

The main purpose of the control scheme is to maintain constant voltage magnitude at the point where load is connected. The main function of the control unit to detect any disturbance in the supply voltage and compare it with the reference signal. Now this unit generate the switching pulses for the semiconductor switch of VSI. The switch is then operated according to the generated pulses in order to create three phase voltages for compensation [3] [1].

F. Operation of DVR

A DVR is a solid state power switching device consist of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformer. The DVR has three modes of operation which are: protection mode, standby mode, injection mode.

G. Protection Mode

The bypass switch can be used to protect the DVR from the over current in the load side due to short circuit or large inrush current. The switch supplying another path for current (S2 will be closed) as shown in figure 2 [7].

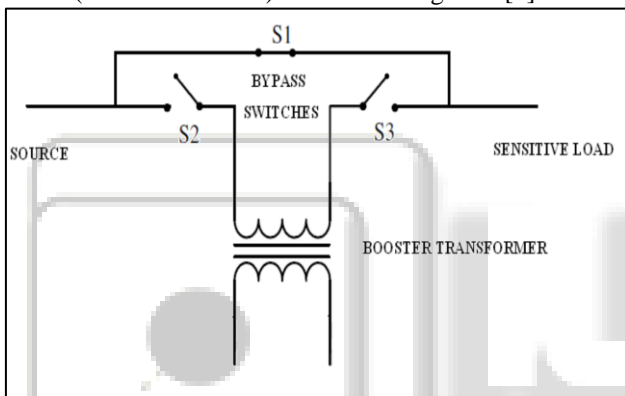


Fig. 2: Protection Mode

1) Standby Mode ($V_{dvr}=0$) [3]

In this mode low voltage (LV) winding of injection/booster transformer is shorted through the use of converter. So there is no switching of power semiconductor devices. Most of time, the DVR will be in this mode of operation [7] [3].

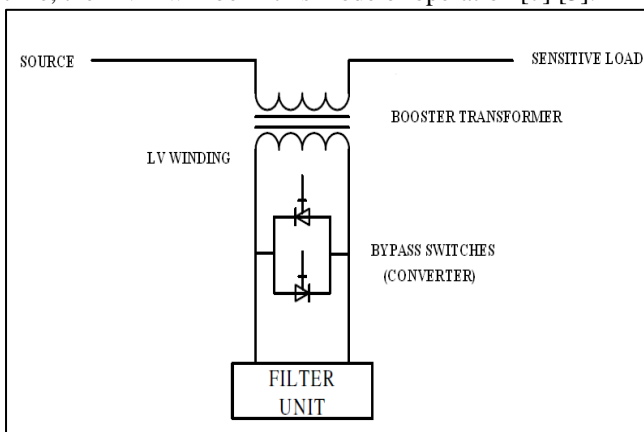


Fig. 3: Standby Mode

2) Injection Mode ($V_{DVR}>0$) [3]

In this mode the DVR will inject a compensating voltage through the booster transformer due to the detection of any disturbance in the supply voltage [1] [3] [7].

II. CONTROL METHODS OF DVR

There are many techniques to implement and control methods of the DVR for power quality enhancements. Most of the DVR system are equipped with a control that is configure to mitigate voltage sag. The main objective of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected under system disturbances. The system only measures the R.M.S voltage at the load point. It means there are no measurement of reactive power. The performance of the DVR is directly affected by the control technique used for driving the inverter, because the inverter is the most valuable part of DVR [7]. There are two types of inverter control strategy which are given below:

- 1) Linear control
- 2) Nonlinear control

A. Linear Control

Linear control is considered as a common method of DVR control. The three main voltage controller are feed forward (open loop), feedback (closed loop) and multi-loop controller.

The feed forward voltage controller can be the primary choice for the DVR. Feed forward control is the simple method of DVR. The supply voltage is continuously monitored and matched-up with a reference voltage; if the difference exceeds a tolerable limit, the DVR injects the required voltage for compensation.

The feedback control method is based on state space system, which can be set up closed loop poles in order to make faster time response [7]. In the feedback control, the load voltage is measured and compared with the reference value; the missing voltage is then supplied by the DVR at the supply bus in a feedback loop. This controller has a high time response but it is complex controller [3].

Multi loop control is used with an outer voltage loop to control the DVR voltage and an inner loop to control the load current.

B. Non Linear Control

In the case of unstable system, the developed model may not work properly. So that all the linear control methods cannot work properly due to their limitations. Then there are the need to use nonlinear controllers such as the artificial networks, fuzzy logic controllers and space vector pulse width modulation [3] [7].

1) Artificial Neural Network (ANN)

One of the non-linear methods of control is artificial neural network (ANN) control and it equipped with adaptive and self-organization capacity. ANN control method normally presented as system of interconnected "neurons" that compute values from inputs by feeding information through the network. The ANN has inherent learning capability that can give superior precision by interpolation. ANN can execute tasks that a linear network cannot perform. ANN control can monitor the non linear relationship based on input and output without the detail mathematical model. ANN control can be classified into feed forward neural networks, feedback neural networks, local approximation neural networks and fuzzy neural network based on structure [7].

2) Fuzzy Control

Fuzzy logic controller is smart choice when precise mathematical formulation are not possible. It is derived from fuzzy set theory. The advantages of this controller are capability to reduce the error and transient overshoot of pulse width modulation (PWM). It offers easy computation and widely available toolboxes and ICs. It is a flexible and spontaneous knowledge based design [7].

III. COMPENSATION METHODS

There are different methods or techniques used for sag compensation are as follow:

A. Pre-Sag Compensation

In pre-sag compensation technique the magnitude and phase angle both are compensated. The difference during sag and pre-sag voltage are detected by DVR and it injects the detected voltage, hence phase and amplitude of the voltage before sags has to be restored [3] [5]. The voltage of DVR is given below:

$$V_{DVR} = V_{prefault} - V_{sag}$$

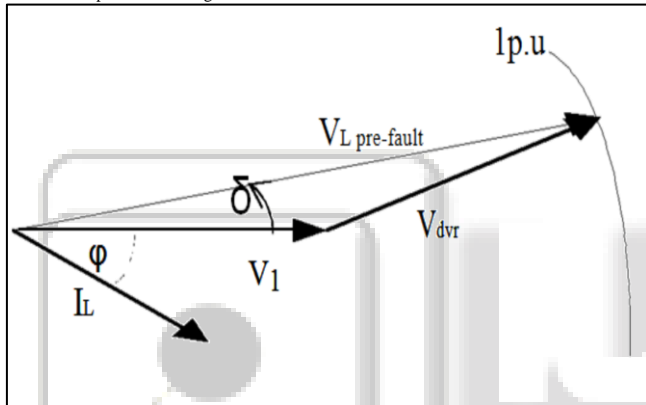


Fig. 4: Pre-sag compensation method

B. In-Phase compensation

This is the most straight forward method. In this method injection voltage is in phase with the source voltage. When the source voltage drops due to sag in the distribution network, then injection voltage produced by the Voltage Source Inverter (VSI) will inject the missing voltage according to voltage drop magnitude [3] [7]. The load voltage is given below:

$$|V_L| = |V_{prefault}|$$

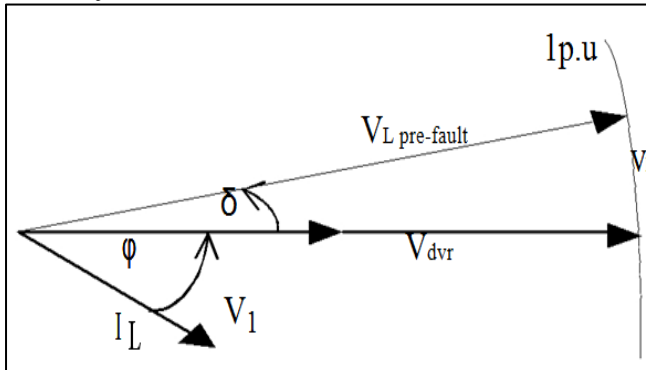


Fig. 5: In-Phase compensation method

C. In-Phase Advanced or Minimum Energy Compensation Method

In this method real power spent by DVR is decreased by minimizing the power angle between the sagged voltage and load current. In this method the values of load current and voltage are fixed in the system so we can change only the phase of the sag voltage. This method is suitable for limited ranges. This method uses only reactive power for the compensation of voltage sag and can perform well in most of the cases.

IV. CONCLUSION

In this paper, the overview of DVR is presented and also different control strategies are offered. The main function of a DVR is the protection of sensitive loads from voltage disturbances in the distribution system. Various topologies and their controllers applied in DVR are explained in this paper. The main advantages of DVR are low cost, simpler implementation; require less computational efforts and its control is simple as compared to other methods. This study also gives useful knowledge for the researchers to develop a new design of DVR for voltage disturbances in electrical system. There is more to come, both in terms of technical development and economic solutions to existing problems.

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